ELSEVIER

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Nuclear Physics A 904–905 (2013) 669c–672c

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Measurement of muon tagged open heavy flavor production in Pb+Pb collisions at 2.76 TeV with ATLAS

Dennis V. Perepelitsa (for the ATLAS Collaboration)[1]

Columbia University in the City of New York, New York, NY 10027, USA
Nevis Laboratories, Irvington, NY 10533, USA

Abstract

Heavy flavor quarks are an important probe with which to study the hot, dense medium produced in heavy ion collisions. Charm and bottom quarks are produced at a relatively early stage of the collision and are predicted to have a smaller gluon radiation due to the dead cone effect. Semi-leptonic heavy flavor decays can be identified by the presence of a muon and separated from the light meson background using a template fitting method. In this talk, the $R_{\rm CP}$ for heavy flavor muons in Pb+Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV with the ATLAS detector at the LHC is presented as a function of muon transverse momentum.

1. Introduction

One of the most striking signatures of the formation of the hot nuclear medium in heavy ion collisions is the suppression of high-$p_{\rm T}$ quarks and gluons traversing the medium, as observed in the dijet asymmetry[1] measured by ATLAS[2]. Measurements of inclusive single hadrons and reconstructed jets primarily measure the effects of the nuclear medium on light quarks and gluons. On the other hand, heavy quarks undergo medium effects in a different way than light quarks and gluons. They are produced through hard processes and thus have a short formation time and their large mass supresses radiation at small angles. Thus, measurements of heavy quark production in heavy ion collisions can allow for a more complete picture of jet suppression.

In this work, the suppression of muons from heavy quark decays is quantified by comparing the yield in central collisions relative to peripheral ones, scaled by the naive geometric expectation. The central to peripheral ratio $R_{\rm CP}$ is given by

$$R_{\rm CP}^{cent} = (1/R_{\rm coll})(1/N_{evt}^{cent})(dN^{cent}/dp_{\rm T})/(1/N_{evt}^{peri})(dN^{peri}/dp_{\rm T}), \quad (1)$$

where the geometric factor $R_{\rm coll}$ is the ratio of the mean number of collisions between central and peripheral events. In the absence of nuclear effects, $R_{\rm CP} = 1$ is expected from the assumption of QCD factorization.

Results from the Relativistic Heavy Ion Collider (RHIC)[3, 4] have shown that above a certain transverse momentum, electrons from heavy flavor decays are suppressed at the same level as leading hadrons. Comparable measurements at the LHC can reveal insights into how jet suppression mechanisms evolve between the two collision systems.

[1]A list of members of the ATLAS Collaboration and acknowledgements can be found at the end of this issue.

http://dx.doi.org/10.1016/j.nuclphysa.2013.02.104

2. Muon reconstruction and centrality determination in the ATLAS detector

Muons are reconstructed through a combination of the inner detector tracking system (ID) and muon spectrometer (MS), which cover the pseudorapidity range $|\eta| < 2.5$ and $|\eta| < 2.7$ respectively[5]. The transverse momentum is determined by a global fit to information from both subsystems. Reconstructed muons are restricted to p_T between 4 and 14 GeV and $|\eta| < 1.05$. Outside of this pseudorapidity region, the tracking performance changes due to features in the detector geometry.

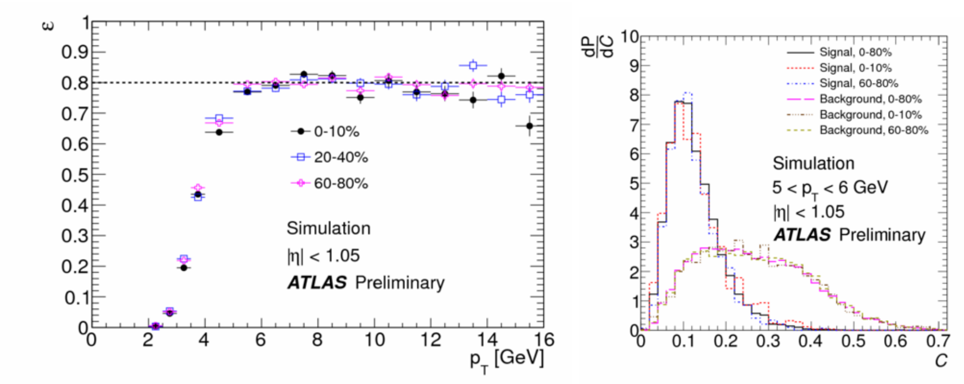

Figure 1: **Left:** Muon reconstruction efficiency ϵ in selected centrality events, as a function of p_T. The dotted horizontal line is the plateau given by a fit to the range $p_T > 5$ GeV. **Right:** Simulated templates for signal and background muons with $5 < p_T < 6$ GeV, for three centrality choices. Please refer to [6] for details.

The performance of the muon reconstruction was evaluated with a Monte Carlo (MC) simulation, obtained by overlaying 5×10^6 `PYTHIA` QCD dijet events with 1×10^6 minimum bias `HIJING` Pb+Pb events and simulating the response of the ATLAS detector with a `GEANT4` description. Figure 1 shows the reconstruction efficiency for muons from semi-leptonic b- and c-decays. The efficiency above $p_T > 5$ GeV is centrality independent and determined to be $\epsilon = 80 \pm 2\%$ from a constant fit. For $p_T < 5$ GeV, the efficiency is centrality dependent, ranging from $64 \pm 2\%$ to $67 \pm 2\%$.

In ATLAS, the centrality of heavy ion collisions is characterized by the sum of transverse energy in the Forward Calorimeters (FCal) at $3.2 < |\eta| < 4.9$. Minimum bias events must pass cuts that include coincident hits in the two Zero-Degree Calorimeter (ZDC) detectors, a timing requirement in the Minimum Bias Trigger Scintillator (MBTS) detectors and a reconstructed vertex. Previous analyses have shown that these cuts select $98 \pm 2\%$ of the inelastic Pb+Pb cross section. The data analyzed for this analysis comprises 53×10^6 minimum bias events from the 2010 Pb+Pb run which corresponds to an integrated luminosity of $\int \mathcal{L} = 7\ \mu\text{b}^{-1}$).

A standard Glauber model and convolution of the parameterized p+p FCal response is used to simulate the Pb+Pb FCal ΣE_T distribution[6]. In this analysis, muon yields from heavy flavor decays are extracted in five centrality categories: 0-10%, 10-20%, 20-40%, 40-60% and 60-80%. The most peripheral bin (60-80%), where hot nuclear matter effects are expected to be small, is used as a common reference in the R_{CP}. The ratio of the mean number of binary collisions ranges from $R_{coll} = 56.7 \pm 6.2$ in $0-10\%/60-80\%$ to 4.9 ± 0.2 in $40-60\%/60-80\%$.

3. Extraction of open-heavy flavor signal and results

Muons consistent with the decay of a heavy quark (signal muons) are separated statistically from muons coming from the decays of $\pi^{\pm}$ and $K^{\pm}$ mesons (background muons) using a template fitting procedure. For this analysis, a composite discriminant is used consisting of two ingredients. The first discriminant, $\Delta p_{loss} = p_{ID} - p_{MS} - p^{MC}_{param}$, compares how much energy is lost by the muon as it moves from the ID through the calorimeter to the MS to the expected value for signal muons in MC. The second discriminant, S, quantifies the angular deflection of the muon as it traverses each stage of the ID. The composite discriminant is constructed according to $C = \left|\frac{\Delta p_{loss}}{p^{MC}_{param}}\right| + r \cdot S$, where $r = 0.07$ is chosen to provide the maximum separation between signal and background. Several simulated template distributions are shown in Figure 1.

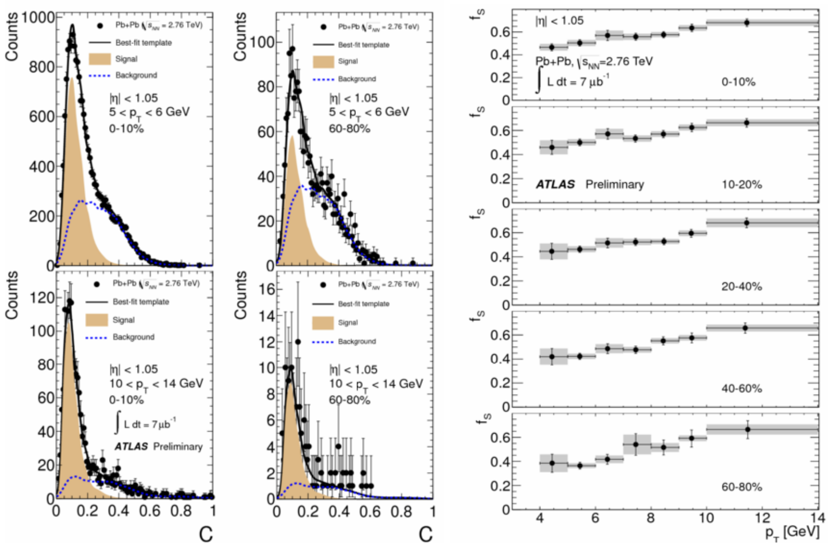

Figure 2: **Left:** Template fits to data for two centrality and muon p_T selections. **Right:** Signal muon fraction as a function of p_T for all centrality bins. Please refer to [6] for details.

Template distributions for signal ($dP/dC|_S$) and background ($dP/dC|_B$) muons are constructed from Monte Carlo, and the composite distribution

$$f_S \; dP/dC|_S + (1 - f_S) \; dP/dC|_B \tag{2}$$

is fit to data, where f_S is the signal fraction. The fitting procedure is implemented by the `RooFit` package and allows a limited adaptation of the templates to data, including a constant shifting along the C axis, rescaling the C axis and a Gaussian smearing of the template distributions. The result of four fits are shown in Figure 2.

The extracted signal fractions for all p_T and centrality bins are shown in Figure 2. To account for the finite statistics in the MC distributions, the fits using templates formed by statistically sampling the distributions and the standard deviation of the results added to the statistical uncertainty in data. There are several potentially important sources of systematic uncertainty, including the possibility of residual centrality dependence in the fitting templates. Additionally, two alternatives to the default fitting procedure were used. The first limits the shifting, stretching and smearing adaptations of the model to the data. The second alternative uses a simple cut on the discriminant to extract the signal yield. To quantify the uncertainty on the composition of pions and kaons in the background muon sample, the contribution from each was separately doubled and the fitting procedure repeated. Finally, the uncertainty from the muon reconstruction efficiency is included in the total. The total systematic uncertainty on the extracted yields ranges from 5% in the highest-p_T, most-central bins to 19% in the lowest-p_T, most-peripheral bins.

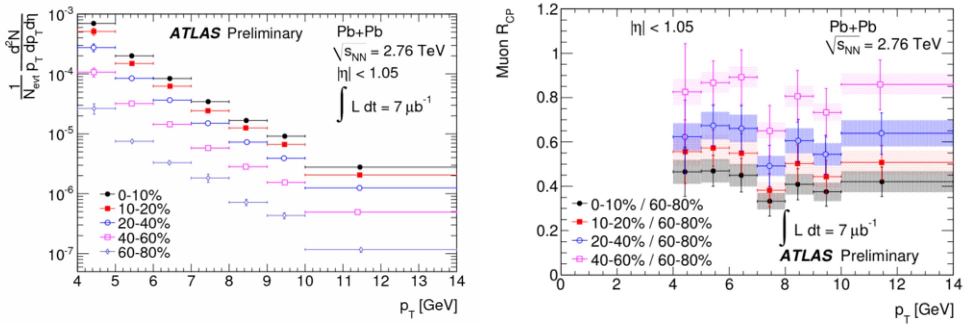

Figure 3: **Left:** Per-event yields of muons from heavy flavor decays in each centrality bin, as a function of p_T. **Right:** Heavy flavor muon R_{CP} in each centrality, as a function of p_T. Please refer to [6] for details.

Figure 3 shows the invariant per-event yield of muons from heavy flavor decays as a function of muon p_T and centrality, as well as the R_{coll}-scaled central to peripheral ratio R_{CP}. Muons from heavy flavor are suppressed by a factor of $\gtrsim 2$ in the most central events, and that this suppression evolves smoothly with centrality. The suppression pattern has only a weak p_T dependence over the entire kinematic range, even at high muon p_T, where the relative contribution from bottom quark decays is expected to dominate over that from charm quarks.

4. Summary

These proceedings present a measurement of open heavy flavor suppression in central heavy ion collisions relative to peripheral collisions. The suppression factor is $\gtrsim 2$ in the most central $0-10\%$ events, a smaller level of suppression than seen in the recent charged particle R_{CP} at ATLAS[7]. This behavior appears to differ from the same level of suppression in charged hadrons and heavy flavor electrons seen at RHIC. Finally, the R_{CP} has at most a weak p_T dependence, in a kinematic region where the charm to bottom contribution to the muon yields is evolving rapidly.

References

[1] ATLAS Collaboration, arXiV:1208.1967
[2] ATLAS Collaboration, JINST 3 (2008) S08003
[3] A. Adare, et al., Phys. Rev. C84 (2011) 044905
[4] A. Adare, et al., Phys. Rev. Lett. 101 (2008) 232301
[5] ATLAS Collaboration, Phys. Let. B707 (2012) 330-348
[6] ATLAS Collaboration, ATLAS-CONF-2012-050
[7] P. Balek, these proceedings